turbo code. Three iterations are employed in the decoder. It can be seen that the degradation of the signal-to-noise power ratio caused by the fully saturated power amplifiers is negligible when the square root raised cosine filter is employed. The turbo code outperforms the convolutional code. When the pulse shaping filter in the IS-95 is employed, the fully saturated power amplifier causes the SNR to degrade by 0.5 dB at BER=10^{-5} for the convolutional coded system, or by 0.7 dB at BER=10^{-6} for the turbo coded system.

FIG. 7 is the bit error rate for $\frac{\pi}{4}$ QPSK employing the present invention with convolutional code or turbo code. The rate is ½ and the constraint length is $K = 7$ for the convolutional code. The Viterbi decoder is employed. The performance is better when the constraint length increases. The rate is ½ and the constraint length is $K = 4$ for the turbo code. Three iterations are employed in the decoder. It can be seen that the degradation of the signal-to-noise power ratio caused by the fully saturated power amplifiers is negligible.

FIG. 8 is the bit error rate for QPSK employing the present invention with convolutional code or turbo code. The rate is ½ and the constraint length is $K = 7$ for the convolutional code. The Viterbi decoder is employed. The performance is better when the constraint length increases. The rate is ½ and the constraint length is $K = 4$ for the turbo code. Three iterations are employed in the decoder.

FIG. 9 is the bit error rate for BPSK employing the present invention with convolutional code or turbo code. The rate is ½ and the constraint length is $K = 7$ for the convolutional code. The Viterbi decoder is employed. The performance is better when the constraint length increases. The rate is ½ and the constraint length is $K = 4$ for the turbo code. Three iterations are employed in the decoder.

CLAIMS

While there have been illustrated and described particular embodiments of the present invention, it will be appreciated that numerous changes and modifications will occur to engineers and scientists skilled in the art. The appended claims intend to cover all those changes and modifications which fall within the true spirit and scope of the present invention.

What is claimed is:

1. A communication system overcoming the distortion that can be caused by any of power amplifiers or up-converters or the channel, the system comprising:

means for using error correcting codes to combat both the distortion caused by either power amplifiers or the channel and the noise at the same time;

means for constructing phase modulated signals which can tolerate the distortion caused by the saturation of power amplifiers or the distortion caused by either up-converters or the channel;

means for minimizing the distortion of saturated power amplifiers to phase-shift-keyed signals at the output of one saturated power amplifier or many saturated power amplifiers;

means for employing any of class-C, class-D, class-E, or class-F power amplifiers, or class-A, class-B, class-AB power amplifiers working in the saturated region;

means for simplifying the processes of design, development and manufacturing of power amplifiers, up-converters, radio terminals and communication terminals;

means for reducing the radio cost, up-converter cost and terminal cost;

means for increasing the reliability of power amplifiers and the reliability of radio terminals;

means for achieving high spectral efficiency in the presence of the distortion caused by power amplifiers;

means for simplifying the terminal design, development and manufacturing;

means for increasing the battery life for communication terminals operated on battery;

means for filtering the received signal with distortion and noise by filters that are matched to the filters in the transmitter;

means for detecting the received signal;

means for estimating parameters in the received signal;

means for tracking the received signal in the presence of distortion and noise;

means for demodulating the received signal using the error correcting codes;

means for achieving the bit error rate performance which is almost the same as the ideal linear BPSK bit error rate when any of class-F, class-E, class-D and class-C power amplifiers, or any of class-A, class-B, class-AB power amplifiers working in the saturated region is employed.

2. A system as recited in claim 1, comprising the encoder for error correcting codes to add redundancy to the information bits by applying turbo code, convolutional code, block code, or low density parity check code to combat the distortion caused by power amplifiers or the channel and to overcome the noise in the channel;
3. A system as recited in claim 1, comprising the modulator to take the input data stream and map the input data to the corresponding phase using the Gray coding for M-ary phase shift keying, M>=2, and variations of phase shift keying;
4. A system as recited in claim 3, wherein said modulator constructs the modulated waveforms in orthogonal channels using finite impulse response filters;
5. A system as recited in claim 4, wherein said modulator uses pulse shaping functions including but not limited to the square-root raised cosine function, raised cosine function, and functions of Hanning, Hamming and Blackman;
6. A system as recited in claim 5, wherein said modulator constructs the linearly modulated waveforms of phase shift keying which do not have constant envelope in orthogonal channels;
7. A system as recited in claim 6, wherein said modulator generates waveforms to minimize the distortion after being amplified by power amplifiers of class-F, class-E, class-D, class-C, or power amplifiers of class-A, class-B, class-AB working in the saturation region;

8. A system as recited in claim 6, wherein said modulator constructs waveforms to minimize the distortion after being transmitted through the channel;
9. A system as recited in claim 1, comprising up-converters and power amplifiers to convert the baseband signal to the signal centered at the carrier frequency and amplify the signal;
10. A system as recited in claim 9, wherein said power amplifiers are class-F, class-E, class-D, class-C, or class-A, class-B, class-AB working in the saturation region, for high DC-to-AC power conversion efficiency;
11. A system as recited in claim 1, comprising an antenna or multiple antenna for transmission and reception of the signal;
12. A system as recited in claim 1, comprising a down-converter to convert the received signal to baseband;
13. A system as recited in claim 1, comprising the sampling circuit to sample the received signal;
14. A system as recited in claim 1, comprising filters in the receiver which are matched to the shaping filters in the transmitter or to the convolution of the impulses response functions of the shaping filter and the power amplifiers;
15. A system as recited in claim 1, comprising correlators to correlate the received signal in orthogonal channels with the prestored waveforms or signals;
16. A system as recited in claim 1, comprising a signal detector which uses the output signals of the correlators to detect the signal or packet;
17. A system as recited in claim 1, comprising parameter estimators to estimate the carrier frequency, phase and symbol timing, using the output of correlators;
18. A system as recited in claim 1, comprising a tracking loop which uses the estimated carrier frequency, phase and symbol timing in the initialization of the loop to track the signal.
19. A system as recited in claim 1, comprising a decoder which can be the iterative decoder, the maximum likelihood decoder or the block decoder.
20. A system as recited in claim 19, wherein said decoder overcomes the distortion caused by power amplifiers or up-converters in the transmitter or by the channel and combats the noise in the channel, the decoding algorithm is optimal to the noise distribution.
21. A system as recited in claim 1, comprising a decoder which can achieve optimal or near optimal bit error rate performance in the presence of both distortion caused by any of the radio power amplifiers or the up-converters or the channel, and noise such as AWGN.
22. A method of minimizing the distortion caused by at least one saturated power amplifier to phase modulated signals, the method comprising of the steps of:

    mapping k bits $\underline{d} = (d_1, d_2, \cdots, d_k)$ at a time to one of $M = 2^k$ phases, the mapped phase is $\phi(\underline{d})$, which is a symbol;

    feeding the coefficient $\cos\phi(\underline{d})$ to a first finite impulse response filter for summing a series of the delayed filter coefficients $\{p(j)\}$ weighted by the symbol coefficients $\{\cos\phi(\underline{d})\}$ to form the filtered in-phase signal;

feeding the coefficient $\sin\phi(\underline{d})$ to a second finite impulse response filter for summing a series of the delayed filter coefficients $\{p(j)\}$ weighted by the symbol coefficients $\{\sin\phi(\underline{d})\}$ to form the filtered quadrature signal.

23. Two pulse shaping filters as recited in claim 22, the first pulse shaping filter to filter the in-phase signal and the second pulse shaping filter to filter the quadrature signal, with the impulse response function $p(t)$ of $L \geq 2$ symbols long, and the pulse shaping function is preferred to satisfy:

$$x(t = kT_s) = \begin{cases} 1 & \text{If } k = L; \\ 0 & \text{Else} \end{cases}$$

where $x(t)$ is the convolution of $p(t)$ and $p(LT_s - t)$, T_s is the symbol time; when the impulse response $p_1(t)$ of the saturated radio or the channel is known to the designer, the function $x(t)$ is the convolution of $g(t) = p(t) * p_1(t)$ and $g(T - t)$, where T is the duration of $g(t)$.

24. Two pulse shaping filters as recited in claim 22, the impulse response function of each filter is any of the square-root raised cosine function with the roll-off factor β close to 1.0, the window functions of Hanning, Hamming, and Blackman, or any function satisfying the condition in claim 23.
25. A modulator implementing phase shift keying as recited in claim 22, the envelope of the modulated signal is not constant.
26. A method of achieving high spectral efficiency through proper pulse shaping in the presence of distortion caused by the distortion of at least one saturated power amplifier or up-converter for communications systems employing phase shift keying.
27. A linear demodulator to demodulate the received signal in the presence of both distortion and noise, the linear demodulator comprising:

a first down-converter to convert the received signal in the in-phase channel to baseband;

a second down-converter to convert the received signal in the quadrature channel to baseband;

a sampling circuit to sample the baseband signals in both the in-phase channel and the quadrature channel;

an analog-to-digital converter to convert the sampled baseband signals to digital signals;

a first finite impulse response filter matched to the shaping filter for the in-phase channel in the transmitter, the filter performs low-pass filtering for the samples in the in-phase channel;

a second finite impulse response filter matched to the shaping filter for the quadrature channel in the transmitter, the filter performs low-pass filtering for the samples in the quadrature channel;

a signal detector to detect the incoming signal using the matched filter output;

a parameter estimator to estimate the symbol timing, carrier frequency offset and carrier phase using the matched filter output;

a tracking loop to track the carrier frequency, carrier phase and the symbol timing;

a decoder to make decisions on the received symbols using the tracking loop output.

28. A method of simplifying the design, development, manufacturing and testing of power amplifiers, up-converters, radio terminals and communications terminals for communications systems employing phase shift keying.
29. A method of increasing the reliability of power amplifiers, radio terminals and communications terminals for communications systems employing phase shift keying.
30. A method of reducing the power amplifier cost, up-converter cost, radio cost and terminal cost for communications systems employing phase shift keying.
31. A method of increasing the battery life for communications terminals operated on battery.
32. A method of reducing the power consumption in transmitters for communications systems employing phase shift keying.